[Claim 12] A reflecting microoptical system as claimed in claim 9, wherein said second surface is aspherical.

[Detailed Description of the Invention]

【0001】

[Field of the Invention]

The present invention relates to a reflecting microoptical system, for example, to a reflecting microoptical system for use in a small-size optical pickup (particularly, high-density optical recording pickup).

【0002】

[Description of the Related Art]

Methods have conventionally been proposed for increasing the numerical aperture (NA) of an objective lens in order to increase the information recording density of optical recording media (optical disks, optical cards, etc.). One of such methods is to dispose an SIL (solid immersion lens) between the optical recording medium and the objective lens. However, the addition of an SIL to an optical pickup increases the weight of the head portion controlled at high speed. To avoid this problem, a method using an SIM (solid immersion mirror) has been proposed (ODF '98, Tokyo, June 16, 1998, "Objective Lenses for DVD & Near Field Optical Disk Pick-up"). The SIM being used is a catadioptric system in which the luminous flux incident on a central portion is reflected at a peripheral portion.

【0003】

[Problem to be Solved by the Invention]

Since the SIM is formed of surfaces defined by a discontinuous expression, the decentration error of each surface is large and the configuration is complicated. Therefore, it is extremely difficult to form the SIM by glass molding using a high-refractive-index glass material. When the SIM is used in a case where uniform light is incident, although the numerical aperture can be increased (the angle with respect to the spot can be increased), a sufficient light quantity cannot be obtained because only a central part of the luminous flux can be used.

【0004】

The present invention is made in view of such a situation, and an object thereof is to provide a reflecting microoptical system that is formed of only two surfaces having a continuous configuration, and has a simple configuration suitable for glass molding.

【0005】

[Means for Solving the Problem]

In order to achieve the above object, a reflecting microoptical system of a first aspect of the invention has, from a long conjugate distance side, a first surface convex to the long conjugate distance side and a second surface convex to a side opposite to the long conjugate distance side, wherein a luminous flux passing through a peripheral part of said first surface to be refracted is reflected at a peripheral part of said second surface, is again reflected at a central part of said first surface and is imaged in a vicinity of a vertex of said second surface.

【0006】A reflecting microoptical system of a second aspect of the invention is characterized in that in the structure of the first aspect of the invention, said

first surface and said second surface are both aspherical.

【0007】 A reflecting microoptical system of a third aspect of the invention is characterized in that in the structure of the first aspect of the invention, said first surface is aspherical.

【0008】 A reflecting microoptical system of a forth aspect of the invention is characterized in that in the structure of the first aspect of the invention, said second surface is aspherical.

【0009】A reflecting microoptical system of a fifth aspect of the invention has, from a long conjugate distance side, a first surface convex to the long conjugate distance side and a second surface being a plane surface, wherein a luminous flux passing through a peripheral part of said first surface is reflected at a peripheral part of said second surface, is again reflected at a central part of said first surface and is imaged in a vicinity of a vertex of said second surface.

【0010】 A reflecting microoptical system of a sixth aspect of the invention is characterized in that in the structure of the fifth aspect of the invention, said first surface is aspherical.

【0011】 A reflecting microoptical system of a seventh aspect of the invention has, from a long conjugate distance side, a first surface being a plane surface and a second surface convex to a side opposite to the long conjugate distance side, wherein a luminous flux passing through a peripheral part of said first surface is reflected at a peripheral part of said second surface, is again reflected at a central part of said first surface and is imaged in a vicinity of a vertex of said second surface.

【0012】A reflecting microoptical system of a eighth aspect of the invention is

characterized in that in the structure of the seventh aspect of the invention, said second surface is aspherical.

【0013】 A reflecting microoptical system of a ninth aspect of the invention has, from a long conjugate distance side, a first surface concave to the long conjugate distance side and a second surface strongly convex to a side opposite to the long conjugate distance side, wherein a luminous flux passing through a peripheral part of said first surface to be refracted is reflected at a peripheral part of said second surface, is again reflected at a central part of said first surface and is imaged in a vicinity of a vertex of said second surface.

【0014】 A reflecting microoptical system of a tenth aspect of the invention is characterized in that in the structure of the ninth aspect of the invention, said first surface and said second surface are both aspherical.

【0015】 A reflecting microoptical system of a eleventh aspect of the invention is characterized in that in the structure of the ninth aspect of the invention, said first surface is aspherical.

【0016】 A reflecting microoptical system of a twelfth aspect of the invention is characterized in that in the structure of the ninth aspect of the invention, said second surface is aspherical.

【0017】

[Embodiment of the Invention]

Hereinafter, reflecting microoptical systems embodying the present invention will be described with reference to the drawings. FIGs. 1, 3, 5, 7, 9, 11, 13, 15 and 17 show the lens constructions of first to ninth embodiments usable as pickup lenses, respectively. In the figures, the surfaces marked

with Si (i=1, 2) are the i-th surfaces counted from the long conjugate distance side, and the surfaces Si marked with asterisks are aspherical. In all of these embodiments, in order that the incident light is imaged on a second surface (S2) after reflected twice within the lens, a totally reflecting coating is applied in the vicinity of the optical axis (AX) of a first surface (S1) and a peripheral zone of the second surface (S2) (hatched parts in FIG. 19). Since the embodiments are systems in which the light emitted from the light source is applied to an optical recording medium, the "long conjugate distance side" is the "light source side".

【0018】 The first and the second embodiments are biconvex pickup lenses in which the first surface (S1) and the second surface (S2) are both aspherical. In the second embodiment, the numerical aperture is greater than that of the first embodiment, and the numerical aperture in the medium exceeds 1. This indicates that the marginal ray is totally reflected at the second surface (S2) and the evanescent light in close proximity of the second surface (S2) is also used for optical recording. The third embodiment is a biconvex pickup lens in which only the first surface (S1) is aspherical. The fourth embodiment is a biconvex pickup lens in which only the second surface (S2) is aspherical.

【0019】 A structure is desirable in which, like in the first to the fourth embodiments, the first surface (S1) convex to the long conjugate distance side and the second surface (S2) convex to the side opposite to the long conjugate distance side are disposed from the long conjugate distance side, and the luminous flux passing through a peripheral part of the first surface (S1) to be refracted is reflected at a peripheral part of the second surface (S2), is again

reflected at a central part of the first surface (S1) and is imaged in the vicinity of the vertex of the second surface (S2). Since the configurations of the first to the fourth embodiments are close to those of biconvex single lenses, like in normal single lenses, aberrations can excellently be corrected with a slight aspherical amount by increasing the curvature of the first surface (S1).

【0020】 By using an aspherical surface for one of the surfaces like in the third and the fourth embodiments, a performance of a wavefront aberration of $\lambda/8$ or less can be realized. By lightening the aberration correction burden on each surface by using aspherical surfaces for both of the surfaces like in the first and the second embodiments, the numerical aperture can be increased. Therefore, by decreasing the beam spot diameter, higher-density optical recording can be handled.

【0021】 The fifth embodiment is a pickup lens in which the first surface (S1) is a convex aspherical surface and the second surface (S2) is a plane surface. A structure is desirable in which like in the fifth embodiment, the first surface (S1) convex to the long conjugate distance side and the second surface (S2) being a plane surface are disposed from the long conjugate distance side, and the luminous flux passing through a peripheral part of the first surface (S1) is reflected at a peripheral part of the second surface (S2), is again reflected at a central part of the first surface (S1) and is imaged in the vicinity of the vertex of the second surface (S2).

【0022】 The sixth embodiment is a pickup lens in which the first surface (S1) is a plane surface and the second surface (S2) is a convex aspherical surface. The seventh embodiment is a pickup lens in which the first surface (S1) is a

plane surface and a second surface (S2) is a paraboloid of revolution. A structure is desirable in which like in the sixth and the seventh embodiments, the first surface (S1) being a plane surface and the second surface (S2) convex to the side opposite to the long conjugate distance side are disposed from the long conjugate distance side, and the luminous flux passing through a peripheral part of the first surface (S1) is reflected at a peripheral part of the second surface (S2), is again reflected at a central part of the first surface (S1) and is imaged in the vicinity of the vertex of the second surface (S2).

【0023】 Aberrations can also excellently be corrected when the first surface (S1) or the second surface (S2) is a plane surface like in the fifth to the seventh embodiments. This structure is advantageous in manufacture because decentration is small. When the second surface (S2) is a plane surface and the first surface (S1) is a high-refractive-index surface like in the fifth embodiment, the angle of the marginal ray increases. Therefore, this structure is advantageous when it is necessary to maximize the resolution. When the first surface (S1) is a plane surface like in the sixth and the seventh embodiments, incident collimated light is not refracted at the first surface (S1), so that no chromatic aberration is generated. Consequently, focus shift does not occur even if the laser wavelength being used varies. In addition, there is a merit that lasers of a plurality of different wavelengths can be used as the light source according to the use. By using a paraboloid of revolution as the second surface (S2) like in the seventh embodiment or by using an aspherical surface close to a paraboloid of revolution as the second surface (S2), a so-called stigmatic lens can be obtained.

【0024】 The eighth embodiment is a pickup lens in which the first surface

(S1) is a concave spherical surface and the second surface (S2) is a convex aspherical surface. The ninth embodiment is a pickup lens in which the first surface (S1) is a concave aspherical surface and the second surface (S2) is a convex spherical surface. A structure is desirable in which like in the eighth and the ninth embodiments, the first surface (S1) concave to the long conjugate distance side and the second surface (S2) strongly convex to the side opposite to the long conjugate distance side are disposed from the long conjugate distance side, and the luminous flux passing through a peripheral part of the first surface (S1) to be refracted is reflected at a peripheral part of the second surface (S2), is again reflected at a central part of the first surface (S1) and is imaged in the vicinity of the vertex of the second surface (S2).

【0025】 At first glance, the configurations of the eighth and the ninth embodiments seem disadvantageous for aberration correction. However, since the light converted into weak divergent light by the first surface (S1) is strongly converged by the second surface (S2), it is easy to correct spherical aberration. Moreover, since the first surface (S1) is a weak concave surface and a ray being angled outward is reflected at the second surface (S2), the width of the luminous flux reflected again at the first surface (S1) is smaller than that of the luminous flux incident on the first surface (S1). Consequently, the area of the totally reflecting coating on the first surface (S1) (the hatched part in FIG. 19) can be reduced, so that the light quantity loss decreases.

【0026】 By using an aspherical surface for one of the surfaces like in the eighth and the ninth embodiments, the wavefront aberration can excellently be corrected to $\lambda/8$ or less. Moreover, by lightening the aberration

correction burden on each surface by using aspherical surfaces for both of the surfaces, the numerical aperture can be increased. Therefore, by decreasing the beam spot diameter, higher-density optical recording can be handled.

【0027】In all of these embodiments, by providing the SIM structure in which the luminous flux passing through a peripheral part of the first surface (S1) is reflected at a peripheral part of the second surface (S2), is again reflected at a central part of the first surface (S1) and is imaged in the vicinity of the vertex of the second surface (S2), a simple configuration formed of only the two surfaces (S1, S2) of a continuous configuration and being suitable for glass molding is achieved. For this reason, the embodiments are easily manufactured by glass molding using a high-refractive-index glass material and are advantageous in light quantity. Moreover, there are merits such that the weight of the head portion does not increase since the embodiments are formed of one lens element and that the light condensed spot decreases since the SIL structure performing in-lens imaging is provided. It is to be noted that the present invention is applicable not only to systems in which the light emitted from the light source is applied to an optical recording medium like the above-described embodiments but also to systems in which divergent light of the light applied to a recording medium from another system is received by a light receiving element.

【0028】

[Examples]

Hereinafter, reflecting microoptical systems embodying the present invention will be described in more detail by providing construction data and graphic representations of aberrations. First to ninth examples shown

below correspond to the above-described first to ninth embodiments. The lens construction views showing the first to the ninth embodiments (FIGs. 1, 3, 5, 7, 9, 11, 13, 15 and 17) show the lens constructions of the corresponding first to ninth examples. FIGs. 2, 4, 6, 8, 10, 12, 14, 16 and 18 show spherical aberrations of the first to the ninth examples.

【0029】 In the construction data of the examples, Si (i=1, 2) represents the i-th surface counted from the long conjugate distance side, ri represents the radius of curvature of the surface Si, d represents the thickness (axial distance) of the lens, and N represents the refractive index of the lens. The surfaces Si marked with asterisks are aspherical. When the optical axis (AX) is the x-axis, the y-axis is within a plane vertical to the optical axis (AX) and the vertex is the point of origin, the aspherical surfaces are defined by the expression (AS) shown below. The wavelength λ of the ray being used, the numerical aperture NA, the focal length fL and the aspherical data of the aspherical surfaces are also shown.

【0030】

$$x = (C \cdot y^2)/\{1+\sqrt{(1-\varepsilon \cdot C^2 \cdot y^2)}\}+\Sigma(Ai \cdot y^i) \quad \ldots \text{(AS)}$$

where x is the amount of displacement from the reference surface in the direction of the optical axis (AX) at a height y, y is the height in a direction vertical to the optical axis (AX), C is the curvature at the vertex, ε is the conic constant, and Ai is the i-th aspherical coefficient.

【0031】

《The First Example》

λ=680nm, NA=0.545(in air), fL=1.834

[Surface] [Radius of curvature] [Axial Distance] [Refractive index]

S1* r1= 3.80245

d= 1.12794 N=1.83375

S2* r2=-16.95438

【0032】

[Aspherical coefficient of the first surface (S1)]

ε = 1.00000000

A4=-0.11292560 $\times 10^{-2}$

A6=-0.43982818 $\times 10^{-3}$

A8=-0.36085168 $\times 10^{-3}$

A10=-0.31090594 $\times 10^{-3}$

【0033】

[Aspherical coefficient of the second surface (S2)]

ε = 1.00000000

A4= 0.29258470 $\times 10^{-2}$

A6= 0.15051402 $\times 10^{-4}$

A8=-0.26476511 $\times 10^{-3}$

A10=-0.20066942 $\times 10^{-3}$

【0034】

《The Second Example》

λ=680nm, NA=0.714(in air), fL=1.834

[Surface] [Radius of curvature] [Axial Distance] [Refractive index]

S1* r1= 3.81254

d= 1.12694 N=1.83375

S2* r2=-16.71558

【0035】

[Aspherical coefficient of the first surface (S1)]

$\varepsilon = 1.00000000$

A4= $0.70512314 \times 10^{-3}$

A6= $-0.61423621 \times 10^{-3}$

A8= $-0.58788514 \times 10^{-3}$

A10= $-0.86000992 \times 10^{-3}$

【0036】

[Aspherical coefficient of the second surface (S2)]

$\varepsilon = 1.00000000$

A4= $0.43189895 \times 10^{-2}$

A6= $-0.56153643 \times 10^{-4}$

A8= $-0.13130585 \times 10^{-2}$

A10= $0.19684362 \times 10^{-4}$

【0037】

《The Third Example》

λ =680nm, NA=0.545(in air), fL=1.834

[Surface]	[Radius of curvature]	[Axial Distance]	[Refractive index]
S1*	r1= 3.80058		
		d= 1.12844	N=1.83375
S2	r2=-16.97581		

【0038】

[Aspherical coefficient of the first surface (S1)]

$\varepsilon = 1.00000000$

A4= $-0.56964867 \times 10^{-2}$

A6= $-0.72642979 \times 10^{-3}$

$A8= 0.48513914 \times 10^{-4}$

$A10= 0.23077580 \times 10^{-3}$

【0039】

《The Fourth Example》

λ=680nm, NA=0.545(in air), fL=1.852

[Surface] [Radius of curvature] [Axial Distance] [Refractive index]

S1	r1= 3.94291		
		d= 1.12794	N=1.83375
S2*	r2=−15.05560		

【0040】

[Aspherical coefficient of the second surface (S2)]

$\varepsilon = 1.00000000$

$A4= 0.34606391 \times 10^{-2}$

$A6= 0.32398624 \times 10^{-3}$

$A8=-0.38641880 \times 10^{-4}$

$A10=-0.36089082 \times 10^{-4}$

【0041】

《The Fifth Example》

λ=680nm, NA=0.545(in air), fL=1.834

[Surface] [Radius of curvature] [Axial Distance] [Refractive index]

S1*	r1= 3.26153		
		d= 1.21331	N=1.83375
S2	r2= ∞		

【0042】

[Aspherical coefficient of the first surface (S1)]

$\varepsilon = 1.00000000$

$A4=-0.50230845 \times 10^{-2}$

$A6=-0.69916764 \times 10^{-3}$

$A8=-0.17985913 \times 10^{-4}$

$A10= 0.14516630 \times 10^{-3}$

【0043】

《The Sixth Example》

λ=680nm, NA=0.545(in air), fL=2.256

[Surface]	[Radius of curvature]	[Axial Distance]	[Refractive index]
S1	r1= ∞		
		d= 1.12794	N=1.83375
S2*	r2= −4.51264		

【0044】

[Aspherical coefficient of the second surface (S2)]

$\varepsilon = 1.00000000$

$A4= 0.13233603 \times 10^{-2}$

$A6= 0.22793168 \times 10^{-4}$

$A8= 0.48985589 \times 10^{-4}$

$A10=-0.19239174 \times 10^{-4}$

【0045】

《The Seventh Example》

λ=680nm, NA=0.667(in air), fL=3.000

[Surface]	[Radius of curvature]	[Axial Distance]	[Refractive index]
S1	r1= ∞		
		d= 1.50000	N=1.83375

S2* r2= −6.00000

【0046】

[Aspherical coefficient of the second surface (S2)]

$\varepsilon = 1.00000000$

$A4 = 0.57870093 \times 10^{-3}$

$A6 = 0.80424469 \times 10^{-5}$

$A8 = 0.13660248 \times 10^{-6}$

$A10 = 0.34335882 \times 10^{-8}$

【0047】

《The Eighth Example》

$\lambda = 680$nm, NA=0.545(in air), fL=2.270

[Surface] [Radius of curvature] [Axial Distance] [Refractive index]

S1	r1=-100.87631		
		d= 1.12794	N=1.83375
S2*	r2= −4.41934		

【0048】

[Aspherical coefficient of the second surface (S2)]

$\varepsilon = 1.00000000$

$A4 = 0.12921255 \times 10^{-2}$

$A6 = 0.14705320 \times 10^{-4}$

$A8 = 0.49466904 \times 10^{-4}$

$A10 = -0.16958548 \times 10^{-4}$

【0049】

《The Ninth Example》

$\lambda = 680$nm, NA=0.558(in air), fL=2.217

[Surface] [Radius of curvature] [Axial Distance] [Refractive index]

S1*	r1=314.51013		
		d= 1.11024	N=1.83375
S2	r2= -4.47227		

【0050】

[Aspherical coefficient of the first surface (S1)]

ε = 1.00000000

A4=-0.48519953 $\times 10^{-2}$

A6= 0.24538094 $\times 10^{-3}$

A8=-0.11191141 $\times 10^{-3}$

A10= 0.44340458 $\times 10^{-4}$

【0051】

[The effect of the invention]

According to the present invention as explained above, a reflecting microoptical system can be realized that is formed of only two surfaces of a continuous configuration, and has a simple configuration suitable for glass molding.

[Brief Description of the Drawings]

FIG. 1 shows the optical path of a first embodiment (a first example);

FIG. 2 shows the aberration of the first example;

FIG. 3 shows the optical path of a second embodiment (a second example);

FIG. 4 shows the aberration of the second example;

FIG. 5 shows the optical path of a third embodiment (a third example);

FIG. 6 shows the aberration of the third example;

FIG. 7 shows the optical path of a fourth embodiment (a forth example);

FIG. 8 shows the aberration of the fourth example;

FIG. 9 shows the optical path of a fifth embodiment (a fifth example);

FIG. 10 shows the aberration of the fifth example;

FIG. 11 shows the optical path of a sixth embodiment (a sixth example);

FIG. 12 shows the aberration of the sixth example;

FIG. 13 shows the optical path of a seventh embodiment (a seventh example);

FIG. 14 shows the aberration of the seventh example;

FIG. 15 shows the optical path of an eighth embodiment (a eighth example);

FIG. 16 shows the aberration of the eighth example;

FIG. 17 shows the optical path of a ninth embodiment (a ninth example);

FIG. 18 shows the aberration of the ninth example;

FIG. 19 is an explanatory view showing the ranges of a totally reflecting coating used in the embodiments.

[Description of Notations]

S1 ... the first surface

S2 ... the second surface